Model for Cumulative Solar Heavy Ion Energy and LET Spectra

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To be presented by Mike Xapsos at the IEEE Nuclear and Space Radiation Effects Conference (NSREC) Technical Session, July 23-27, 2007 and to be published on http://rahome.gsfc.nasa.gov

Outline

- **Introduction to PSYCHIC* Model**
- **Solar Protons**
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- **Solar Heavy Ions**
  - **Data**
  - **Results**
  - **Summary**

***Prediction of Solar particle Yields to CHaracterize Integrated Circuits**

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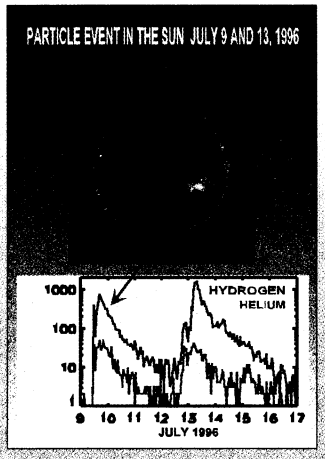
Introduction

- It is especially important to have predictive models for solar particle event fluences and fluxes for missions away from Earth's magnetic field.
  - Geosynchronous
  - Polar
  - Interplanetary
- Current solar heavy ion models:
  - CREME96 uses October 1989 event as a worst-case event
  - Cumulative fluence models not well developed
- This work is based on advanced statistical methods so that risk/cost/performance tradeoffs can be evaluated during design phase.

Solar Proton Model

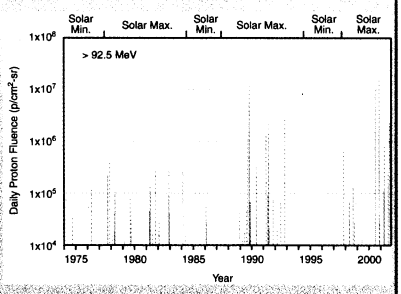


Solar Proton Data

- **Based on the IMP and GOES series of satellite data spanning time period from 1966 to 2001**
  - **Energy range from 1 to 330 MeV**
  - **Solar maximum and solar minimum time periods treated separately**

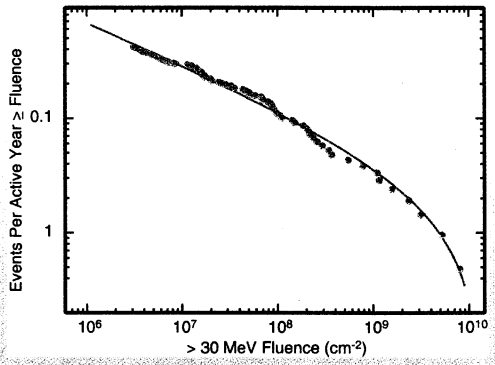
Distribution of Event Magnitudes

- **Solar particle events appear to be probabilistic in nature so it is important to accurately model the distribution of event magnitudes.**
- **However, the data are limited**
  - **Can make selecting a distribution difficult and arbitrary**
- **Maximum Entropy Principle**
  - **Method for making arguably the best selection of a probability distribution compatible with known information**



Distribution of Event Magnitudes

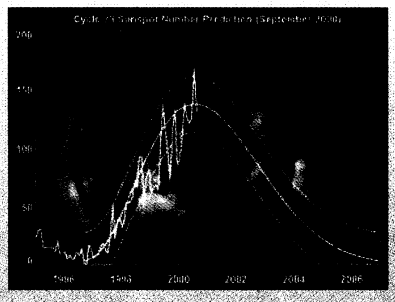
- **Resulting solution using maximum entropy approach is a truncated power law function in the event magnitude during solar max**
- **Describes essential features of the distribution**
  - **Smaller event sizes follow power law function**
  - **Larger event sizes fall off much more rapidly**

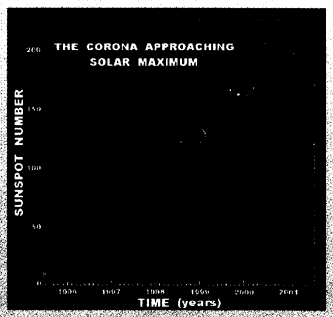


M.A. Xapsos et al., IEEE TNS, Dec. 1999

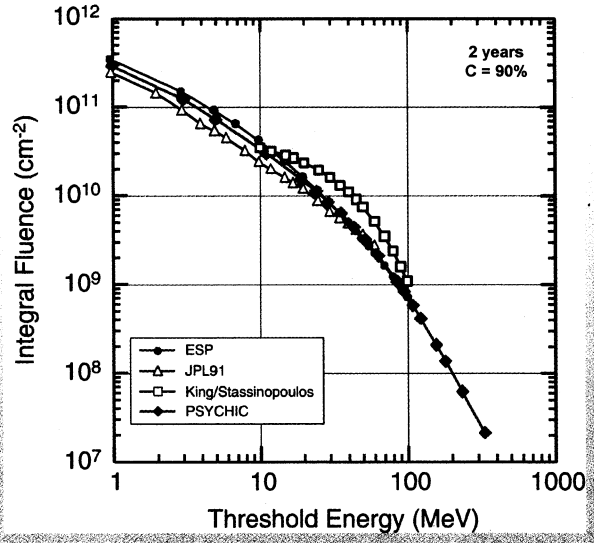
Cumulative Fluence During Solar Maximum

- **Once the distribution of event fluence magnitudes is known, the cumulative fluence during a mission can be calculated.**





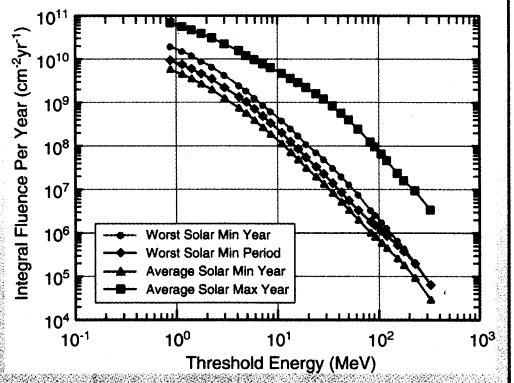
Model Comparisons for Solar Maximum



M.A. Xapsos et al., IEEE TNS, Dec. 2004

Cumulative Fluence During Solar Minimum

- **Solar minimum model is important for missions planned mostly or entirely for this time period.**
- **PSYCHIC model contains 3 solar minimum flux levels to allow varying degrees of conservatism to be used in design process.**



M.A. Xapsos et al., IEEE TNS, Dec. 2004

Summary – Solar Proton Model

- A complete solar proton model has been developed
  - Cumulative fluences and worst case events
  - Energy range 1 to 330 MeV
  - Covers entire solar cycle
- Used at GSFC for spacecraft design
- Implemented in SPENVIS and OMERE 3.1
- Validated with measurements by CREDO instrument on MPTB*

*See C.S. Dyer et al., IEEE Trans. Nucl. Sci., vol. 49, pg. 2771-2775 (Dec. 2002)

Solar Heavy Ion Model

Heavy Ion Data

Predominant Elements:	Measurement Period:	Energy Range (MeV/n):	Data Source:
Alpha Particles	1973 - 2001	1 - 200	IMP-8, GOES
C, N, O, Ne, Mg, Si, S, Fe	1997 - 2005	7 – 140 (element dependent)	ACE/SIS

Less prevalent elements are scaled to above energy spectra using either ISEE-3 satellite data or a photospheric abundance model corrected for the first ionization potential effect.

Heavy Ion Energy Spectra